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Abstract

This investigation reports on gemination in Tarifit, a variety of Berber language spoken in the North Eastern region of Morocco. It presents results of a simultaneous X-ray and acoustic investigation of singleton and geminate voiced and voiceless stops in three different word positions (initial, intervocalic, and final.) The acoustic parameters examined show that geminates are systematically produced with a longer closure duration than their singleton counterparts, regardless of the position of the geminate stops within the word. Consonantal gemination, however, does not affect the duration of adjacent vowels, neither does it affect the duration of VOT (including burst-release for voiced stops). Concerning X-ray data, measurements obtained from sagittal profiles show that contact-extents (maximum value for contact) are longer for geminate consonants than for their singleton counterparts. Interestingly, this holds true even for voiceless stops in word-initial position.

1 Introduction

The *aim* of this investigation is to analyze the behaviour of singleton and geminate plosives, based on acoustic and X-ray data, for 2 native speakers (SF and SK) of Tarifit Berber. Geminates have been examined in different acoustic studies, especially in intervocalic position. One consistent characteristic shared by these segments in this context is that they are significantly longer than their singleton counterparts (see Ridouane [8] for a review of 27 languages contrasting singletons with geminates). The acoustic characteristics of initial and final geminates have not been subject to as much investigation. Some studies have also been carried out on the articulatory characteristics of geminate consonants. Both Farnetani [3] for Italian and Byrd [2] for American English conducted electropalatographic investigations on stops, and have shown that the amount of tongue palate contact is larger for geminates (heteromorphemic geminates for English) than for single stops, and also that there is a general increase in the extent of a tongue-palate contact with increasing closure duration. The same results were obtained by Ridouane [9] and Kraehenman & Lahiri [4] based on EPG data from Tashlhiyt Berber and Turgovian Swiss-German, respectively. These two studies, in addition, showed that these articulatory differences were maintained even for voiceless stops in utterance-initial position, where durational differences between singletons and geminates are not detectable by listeners. Smith [10] examined lip and tongue movements in single and geminate consonants in Japanese and Italian, and found out that the closing movements of the lips were slower for the geminates compared with single consonants. Löfqvist and Gracco [6] examined events during bilabial stop consonant production using kinematic recordings, in combination with records of oral air pressure and force of labial contact. Their results suggest that the lips are moving at a high velocity when the oral closure occurred. Mechanical interactions between the lips were also depicted, showing tissue compression and the lower lip moving the upper lip upward.

The authors also studied lip and jaw kinematics in bilabial stop consonant productions. They proposed the idea of a virtual target for lip movements, and also noted that it might be applicable to other articulators as well. The result they found was compatible with the hypothesis that one target for the lips in a bilabial stop production is a region of negative lip aperture.

According to these authors, a negative lip aperture implies that to reach their virtual target, the lips would have to move beyond each other. Such a control strategy would ensure that the lips will form an air tight seal irrespective of any contextual variability in the onset positions of their closing movements.

Subsequently, Löfqvist [7] studied lip kinematics in long and short stops and fricatives, using a magnetometer system. Based on earlier work showing that the lips were moving at a high velocity at the oral closure, it was hypothesized that speakers could control closure/constriction duration by varying the position of a virtual target for the lips. According to this hypothesis, the peak vertical position of the lower lip during the oral closure/constriction should be higher for the long consonants than for their shorter counterparts. This would result in the lips staying in contact for a long period. The data show that this is the case for Japanese subjects and for one Swedish subject who produced non-overlapping distributions of closure/constriction duration for the two categories.

An X-ray study of French consonants by Vaxelaire [11] suggest that the area of tongue palate contact is larger for the long (abutted) stops than for the short ones. When speech rate was increased, these differences in contact extents were further enhanced, with a remarkable increase in the area of tongue palate contact for the long stops. The author's hypothesis ([12]) in interpreting this finding is as follows: in fast speech, the speaker has to reduce transition times in order to maintain linguistic differences, thus resulting in an increase in force of execution of gestures, which provokes an increase in tongue body impact against the hard palate, for the long stops.

2. METHOD

The entire *corpus* consisted of 54 meaningful sentences, comprising 27 minimal pairs contrasting singleton and geminate consonants (plosives and fricatives). The speech material analysed here consists of 15 minimal pairs, contrasting singleton stops with their geminate counterparts, in three positions: word initial, word medial, and word final. Target sequences were thus of the type V1(#)C(C)(#)V2. Note that in initial and final positions, all consonants were respectively preceded and followed by a vowel (V1 or V2) contained in the carrier sentence, thus allowing for measurement of consonantal closure and VOT (see below).

The plosives examined were: /t, d, k, g, q/ *vs.* /tt, dd, kk, gg, qq/. Due to experimental conditions (exposure to X-ray), each sentence was produced once at a normal (self-selected) speaking rate. Note that all pairs of sentences had the same number of syllables. The X-ray films (25 frames per second), together with a simultaneous audio recording of the speakers' productions, are part of the Phonetics Institute of Strasbourg X-ray database (see Bothorel *et al.*, [1] ; Vaxelaire, [13] for details on acquisition and measurement procedures).

With the help of a grid (Bothorel *et al.*, [1]), *measurement parameters* (semi-automatic, then corrected manually) for *vocal tract configurations* were determined related to tongue tip-to-alveolar ridge, tongue body-to-soft palate, and tongue body-to-uvula contact-extents (mm). Jaw opening (mm) and constriction width (mm) related to the subsequent vowel in word-initial position, to the flanking vowels in word-medial position, and to the preceding vowel in word-final position, were also measured.

Temporal events were detected on the *audio* signal, and specific timing relations between these events allowed determining acoustic durations (ms) that correspond to articulatory opening and closing gestures. Thus vowel durations were specified as intervals between onset and offset of a clear formant structure. Corollary, closure duration was measured, between vowels, from offset of V1 to the burst-release. VOT was also acquired as the interval between the burst-release of the plosive and onset of a clear formant structure of the subsequent vowel, V2.

It is *hypothesised* on the *acoustic level* that, as reported in the literature, geminates would have longer closure durations than singletons (*hypothesis 1*). The duration of flanking vowels may be affected by that of geminate consonants (*hypothesis 2*): they would be shorter in this environment (Lehiste *et al.*, [5]), in case of syllable isochrony. VOT could be longer for both voiced and voiceless geminates, as their occlusion phase is usually remarkably long, thus retarding onset of voicing, due to high intra-oral pressure (*hypothesis 3*). Moreover, it is worth mentioning that higher intra-oral pressure would also tend to make voiced stops partially devoiced and thus produced with a longer burst-release phase, compared to a completely voiced stop (Ridouane, [9]).

On the *articulatory level*, as shown by Vaxelaire ([12, 13]), contact-extent, partly underlying consonantal closure, would be correlatively longer for geminates (*hypothesis 4*). If geminates do shorten adjacent vowels, jaw opening and constriction width may vary as a function of this coarticulatory influence (*hypothesis 5*).

3. RESULTS

Results given here are based on raw data, and rarely on statistics, due to experimental conditions (1 repetition per item). Some of them should therefore be considered as tendencies. Figure 1 summarises the effect of gemination on each of the acoustic parameters examined. It shows the mean durations for each measurement across speakers, places of articulation, and position. Consonantal duration of geminates is noticeably longer than corresponding singletons (207 ms for geminates (SD = 21) and 96 ms for singletons (SD = 12)). This is true for all types of consonants (voiced and voiceless alveolars, velars and uvulars) in the three positions (initial, intervocalic, and final), for the two subjects. This result is in line with *hypothesis 1*.

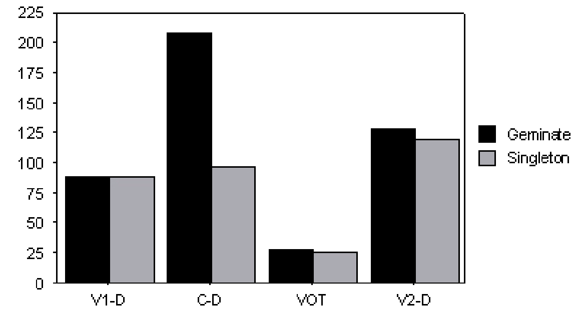

Figure 1. Mean duration values (ms) showing the effect of gemination on the acoustic parameters examined (V1-D = preceding vowel duration, C-D = consonant duration, VOT = release duration for voiceless and voiced stops, V2-D= subsequent vowel duration).

It is noticed that consonantal gemination did not affect the duration of preceding vowels (88 ms before geminates (SD = 10) and 87 ms before singletons (SD = 10)). It did not affect the duration of the following vowels, neither (127 ms following geminates (SD = 36) and 119 ms following singletons (SD = 33)). *Hypothesis 2* is consequently not verified. Likewise for VOT values which are also similar for both categories (*hypothesis 3*). This is true even for voiced stops (22 ms for geminates (SD = 6) and 21 ms for singletons (SD = 5)).

Articulatory analyses, from the X-ray data, were carried out to see how the phonological contrast is highlighted on the articulatory level. Measurements obtained from mid sagittal profiles show that contact-extents (maximum value for contact) are longer for geminate consonants than for their singleton counterparts (see *Figure 2*, for an illustration).

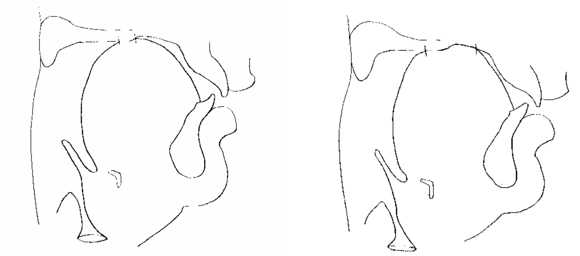

Figure 2. *This figure shows velar contact extents for /g/ (left) vs. /gg/ (right). Speaker SF.*

This observation is valid, in an intra-speaker pairwise comparison, for all linguistic categories examined, *i.e.* alveolars, velars and uvulars, and for both speakers (thus corroborating *hypothesis 4*). Minimal differences in all instances were clear-cut, *i.e.* 5 mm (with a 0.5 mm error margin). In the case of uvulars, the tongue body pushes the uvular (speaker SK) or both the uvular and the velum (speaker SF) against the pharyngeal wall, with a larger contact extent for the geminate consonant. It should be noted that this difference in obstruent strategy is always systematic, across several images (see *Table 1* for data from both speakers). The tongue-body to velum and uvular contact in the case of speaker SF explains noticeable values of contact extent for these uvular consonants.

Table 1. *This table gives raw contact extent data for singletons vs. geminates. Speakers SF and SK*

	plosives	/t/	/tt/	/k/	/kk/	/q/	/qq/	/d/	/dd/	/g/	/gg/
SF	contact extent (mm)	11	16	10	15	30	35	11	17	8	21
SK	contact extent (mm)	6	11	7	13	5	15	9	18	7	14

Jaw opening and constriction width did not show any systematic coarticulatory behaviour, contrary to our expectations (*hypothesis 5*).

4. CONCLUSIONS

Data for singleton and geminate plosives have been analyzed and a relevant measure has been unveiled for gemination in Tarifit Berber: articulator contact-extent. Together with closure duration, contact extent is indeed a robust parameter, since it is also valid in distinguishing the two linguistic categories across consonantal contexts, word positions and subjects. Moreover, as larger contact extents for geminates seem to correspond to longer consonantal durations for this category of consonants (and *vice versa* for singletons), it is suggested that there should be some relationship between the two parameters, a relationship which needs to be unfolded.

In line with Vaxelaire's [12] hypothesis, and also results found by Löfqvist and Gracco [6], our data suggest that the tongue is moving at a higher velocity for geminates compared to singletons, at oral closure. One articulatory target, amongst others, for single stops would be a given amount of contact extent. A different target would be specified for geminates, with higher tongue velocity and force, and consequently enhanced tongue palate (hard and soft) impacts, resulting in larger contact extents. It is reckoned that these interactions between the tongue and the palate result from both spatiotemporal control strategies and mechanical factors, as shown by varying degrees of tongue tissue compression against the palate. For both singletons and geminates, control strategies would ensure that the tongue will form the basic and necessary air tight seal. However, for geminates, an additional increase in contact extents, resulting from mechanical factors, would contribute to guaranteeing phonological distinctions. Such conjectures do, of course, call for further investigations, especially related to tongue kinematics and oral air pressure during the productions of these stops.

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References

[1] Bothorel, A., Simon, P., Wioland, F. & Zerling, J-P. (1986). Cinéradiographie des voyelles et consonnes du français, recueil de documents synchronisés pour quatre sujets: vues latérales du conduit vocal, vues frontales de l'orifice labial, données acoustiques, *Publication de l'Institut de Phonétique, Strasbourg.*

[2] Byrd, D. (1995). Articulatory characteristics of single and blended lingual gestures. In *Proceedings of the 18th International Congress of Phonetic Sciences,* edited by K. Elenius and P. Branderud, Stockholm,Vol. 2, pp 438-441.

[3] Farnetani, E. (1990). V-C-V lingual coarticulation and its spatiotemporal domain, In *Speech Production and Speech Modelling*, edited by W. Hardcastle and A. Marchal (Kluwer, Dordrecht), pp. 93-130.

[4] Kraehenmann, A. and Lahiri, A. (2008). Duration differences in the articulation and acoustics of Swiss German word-initial geminate and singleton stops. *Journal of the Acoustical Society of America* 123, 4446-4455.

[5] Lehiste, I., Tatham, M. & Morton, K. (1973). An instrumental study of consonant gemination. *Journal of Phonetics* 1, 131-148.

[6] Lövqvist, A., and Gracco, V. (1997). Lip and jaw kinematics in bilabial stop consonant production, *Journal of Speech and Language Hearing Research* 40, 877-893.

[7] Lövqvist, A. (2005). Lip kinematics in long and short stop and fricative consonants, *Journal of the Acoustical Society of America 117*, 858-878.

[8] Ridouane, R. 2003. Suite des consonnes en berbère: phonétique et phonologie. *Thèse de Doctorat, Université Sorbonne-Nouvelle*.

[9] Ridouane, R. (2007). Gemination in Tashlhiyt Berber: an acoustic and articulatory study. *Journal of the International Phonetic Association* 37 (2), 119-142.

[10] Smith, C. L. (1995). Prosodic patterns in the coordination of vowel and consonant gestures, In *Laboratory Phonology* 4: *phonology and phonetic evidence, edited* by B. Connell and C. Arvaniti (Cambridge U. P., Cambridge), 205-222.

[11] Vaxelaire, B. 1995a. Single *vs*. double (abutted) consonants across speech rate. X-ray and acoustic data for French. *Proceedings of the 13th International Conference on Phonetic Sciences* 1, 384 – 387.

[12] Vaxelaire B. 1995b. Etude acoustique et articulatoire des consonnes simples et doubles du français, en fonction de la vitesse d'élocution. Données cinéradiographiques et acoustiques. *Travaux de l'Institut de Phonétique de Strasbourg (TIPS)* 25, 67 – 93.

[13] Vaxelaire B. 2007 Le geste et la production de la parole. Résultats et implications d'études quantitatives cinéradiographiques. Habilitation *à Diriger des Recherches (HDR).* Université Marc Bloch – Strasbourg 2, 133p.